II.

THE EFFECT OF CERTAIN STIMULI UPON THE ATTENTION WAVE.

By R. W. Taylor, M. A.

The dominant place of attention in consciousness gives great interest to all experiments along that line. This paper deals with one of the minor phases of the duration of the attention. Our more particular problem was to investigate the influence of certain stimuli upon the length of the attention waves in the hope that the results would throw some light upon the much disputed question as to whether the waves were of central or of peripheral origin.

The Masson disk was used to give the minimal stimulus necessary, as it is at once more easily manipulated and the results obtained are less likely to be influenced by distracting stimuli than if a minimal sound or pressure is chosen. In these experiments the disk used was 32½ cm. in diameter, and had drawn upon one radius 15 dots, each 5 mm. long, 4 mm. wide, and separated from each other by spaces of 5 mm. The fluctuations were recorded by a Marey tambour upon the horizontal drum described by Slaughter.[1] At the rate used a single record lasted 8¾ minutes. The time was recorded in fifths of seconds by a Jacquet-Verdin chronograph. The reagent sat at a distance of two meters from the disk. Pressure upon the receiving tambour marked the time of appearance of the gray lines, and relaxation of pressure the time of disappearance.

The experiments were begun in February, 1900, and continued until June of that year. Mr. Schiller (S.), Mr. Bair (B.) and Miss Earhart (E.) acted as subjects. All had had some previous psychological training, and were careful, interested observers.

We shall consider the results obtained from S. first. The experiments were performed by taking a series of readings under normal conditions lasting over a period of three or four minutes, and then one or two series of readings under the influence of different kinds of stimulation during the last four or five minutes. The stimuli used for S. consisted of the pain from an induction current applied by dry electrodes to the left

[1] This *Journal*, p. 313.

hand, the complex set of impressions obtained from smoking, and the odors of balsam and ether. The induction current was adjusted to give a decidedly painful sensation, but of course it was impossible to obtain any measure of its strength or even to keep it constant during the experiments. The smoking was peculiarly pleasant to S. as he had been an inveterate smoker, but had abstained for some months before the experiments. It is not meant that this gave a pure sensation of any kind or that the experiment is not complicated by the direct narcotic effect of the tobacco. As will be seen in the discussion of the results we are concerned only to show that the attention waves respond to various influences in much the same way that the better understood physiological rhythms respond, rather than to trace accurately the effect of definitely isolated stimuli upon them. Only one tracing was taken with the odors, and the odors chosen were some that happened to be on hand, and are not those likely to give the most typical results. The same objection is of course to be brought against the ether as against the nicotine, and can be met in the same way. The results obtained from odors are only of value in confirming those obtained from other substances.

The results of the experiments on S. are given in Table I. The first three columns show the time in seconds of the visible period, of the period of invisibility, and the total period under the normal conditions. The second series of three columns gives corresponding values obtained during stimulation by the induction current, and the third series, similar values while smoking. At the bottom of the Table is shown the result of the stimulation by the different odors. Each tracing is given separately with its date, that the variations from day to day may be noted. Each tracing contained from eighty to ninety complete waves, and the Table gives the results of 850 observations. Several of the early tracings were omitted that the training might be nearly constant throughout.

The most notable fact in the results of the experiments is that the length of the total wave is shortened by the electrical stimulation. It is also noticeable that the greater part of the shortening comes during the period of visibility,—the visible period is decreased in length more than a second, while the period of invisibility is only ¾ secs. less. The results of the experiments while smoking are no less marked than in the preceding case, but the changes are in the opposite direction. In these tracings the total length of the wave is very noticeably increased, but in the present instance the increase is entirely in the visible portion of the wave, while the period of invisibility is actually decreased. These statements hold not merely for the average as a whole but for the average of

TABLE I.

Duration of Attention Waves in Seconds.

Reagent S.

	NORMAL.			INDUCTION CURRENT.			WHILE SMOKING.		
TRACING DATE.	Visible	Not Visible	Total	Visible	Not Visible	Total	Visible	Not. Visible	Total
Mar. 21 (8)	6.3	5.1	11.4	5.4	5.5	10.9	—	—	—
Apr. 2 (11)	4.5	3.8	8.2	—	—	—	6.9	3.7	10.6
Apr. 2 (12)	—	—	—	4.7	3.8	8.5	6.0	3.0	9.0
Apr. 4 (15)	6.9	4.4	11.3	—	—	—	9.6	5.2	14.7
Apr. 4 (16)	6.8	4.0	10.8	5.4	3.7	9.2	—	—	—
Apr. 12 (18)	4.8	3.7	8.5	3.3	4.5	7.8	6.1	5.0	11.1
May 2 (19)	6.3	6.5	12.8	3.8	4.8	8.6	—	—	—
Average[1]	6.0	4.9	10.9	4.5	4.5	9.0	7.1	4.2	11.3
				WITH ETHER			WITH BALSAM		
May 2 (20)	6.7	6.7	13.4	5.0	5.4	10.4	3.3	4.1	7.44

[1] Includes normal of 20 below.

each tracing separately. The single tracing taken with odors as stimuli shows the same general effect as those taken during the stimulation with an electric current, except that the results are even more marked. In both cases the first effect of the odor was to increase the length of the stimulation, but the second effect was to shorten it very greatly.

When it comes to a consideration of the effect of the stimuli upon attention efficiency it is evident that the results given in the Table do not afford a direct means of comparison. The length of the entire wave varies, not merely the length of one part. It occurred to us, therefore, that the ratio of the period of visibility of the gray rings to the period of their invisibility would afford a direct measure of the attention efficiency, under the varying conditions. The results were tabulated in terms of this relation and the results for all subjects are shown together in Table II. The figures show the quotients obtained by dividing the period of visibility by the period of invisibility.

It will be seen in the table that the effect upon the attention efficiency is just as marked and nearly as constant as was the effect upon the length of the attention wave. In every tracing we find that the average efficiency of the attention is decreased during the electrical stimulation and is increased during the time that the subject smoked except in the case of No. 18. This tracing had been preceded by another which was discarded because the pneumograph had been drawn tight enough to be uncomfortable. As S. had been smoking during a part of that tracing the second indulgence might be expected to be

TABLE II.

Efficiency of Attention Measured in Ratio of Visible to Invisible Period.

(Subjects S., E. and B.)

S. Subject.				E. Subject.			B. Subject.		
Tracing.	Normal.	Induction Current.	Smoking.	Tracing.	Normal.	Induction Current.	Tracing.	Normal.	Induction Current.
8	125	97	—	13	115	123	21	236	262
11	119	—	187	14	150	87	22	214	253
12	—	126	204	24	158	133	23	222	284
15	158	—	184	25	151	183			
16	170	147	—						
18	130	73	123						
19	96	81	—						
20	100	—	E[1] 92 B[2] 81						
Ave.	125	102	170	Ave.	143	134	Ave.	223	267

[1] Odor of Ether. [2] Odor of Balsam.

less pleasurable. The smoking also had immediately succeeded the electrical stimulation, and it is probable that there had not been sufficient time allowed for complete recovery from that effect. The two odors also show a reduction of attention efficiency, but again the observations are so few in number that they can be regarded only as confirmatory in character.

The results from E. show variations from those just reported, and are on the whole not so unambiguous. The results as regards the length of the waves are brought together in Table III. The effect upon attention efficiency is shown in Table II above. The Table itself is easily understood from the descriptions of the preceding Tables.

TABLE III.

Duration of Attention Waves.

E. Subject.

	Normal.			With Induction Current.		
No. and Date.	Visible.	Not Visible.	Total.	Visible.	Not Visible.	Total.
13 (Apr. 2)	10.1	8.8	18.9	14.6	11.9	26.4
14 (Apr. 2)	12.2	8.1	20.3	10.2	11.7	21.8
24 (May 7)	19.4	12.3	31.7	18.9	14.3	33.2
25 (May 7)	19.3	12.8	32.0	24.5	13.4	38.0
Ave.	15.3	10.5	25.8	17.1	12.8	30.0

It will be seen that here again the effect of the electrical stimulus is well marked and constant but that it is in the opposite direction to that shown by S. There is a decided lengthening of the wave rather than a shortening. There is evident in these tracings the unusual length of the attention waves that Slaughter found for the same subject. If we accept his conclusions that the attention waves of E. are related to a different physiological rhythm it would be easy to explain the apparent anomalies in the results as compared with the other persons. There are also anomalies in the effect of the stimulation upon attention efficiencies. It will be seen that in two tracings the attention efficiency is considerably increased, while in the other two tracings recorded the efficiency is very markedly decreased. These anomalies can all be discussed to better advantage after we have considered the concomitant effect of the current upon the breathing rhythm.

Table IV gives the corresponding results for B.

TABLE IV.

Duration of Attention Waves.

Reagent B.

No. and Date of Tracing.	Normal.			With Induction Current.			After Stimulation.		
	Visible	Not Visible	Total	Visible	Not Visible	Total	Visible	Not Visible	Total
21 (May 3)	4.9	2.1	7.0	5.2	2.0	7.2			
22 (May 4)	6.0	2.8	8.8	6.8	2.7	9.5			
23 (May 4)	6.0	2.7	8.7	7.9	2.8	10.7	5.4	2.8	8.2
Ave.	5.6	2.5	8.1	6.6	2.5	9.1	5.4	2.8	8.2

Here we see that the results of stimulation are again marked, but are in every case directly opposed to those noticed in S. In each the wave is slowed and the attention efficiency is increased. The only explanation to be offered for this result is that B. is of a very phlegmatic temperament and in perfect health.

In general, then, we find that stimulation by the induction current affected S. by uniformly quickening the rhythm of the attention fluctuation and decreasing the efficiency of the attention, for B. it just as uniformly slowed the rhythm and increased the efficiency, while for E. the wave was uniformly lengthened, but the efficiency was now increased, and now decreased. Smoking (a pleasant stimulus) lengthened the waves and increased the efficiency of the attention for S. The others were not tested for pleasurable reactions as neither smoked and no definitely pleasant stimulus suggested itself. The general results are just as confused as have been the results of re-

cent investigations upon the influence of pleasure and pain upon the volume of the members.

The results so far obtained, both from the definiteness of the fact of a reaction of some kind and the great divergence in the results for different people, suggested that it might be of value to make a simultaneous study of the effects of these stimuli upon the respiration. The respiration was chosen because of the ease and certainty with which the results could be obtained. In the light of Slaughter's results it would have been much more desirable to have made the comparison with the Traube-Hering waves, but the uncertainty of their appearance and the difficulty that attaches to obtaining a good plethysmographic tracing under varying stimulation compelled us to let that go over to another time.

During this later series of experiments the respiration was recorded on the same drum as the attention waves by means of a Fitz pneumograph and a Marey tambour that wrote parallel to the one that recorded the attention waves. The results show in most cases a correspondence between the effects upon the respiratory and the attention rhythms.

The results are collected in Tables V, VI and VII below.

There are again individual differences, so that each subject must be discussed separately. For S. we find a perfect correspondence between the breathing and the attention waves. The electric stimulation shortened both, while smoking lengthened both. The electrical stimulus had an opposed effect upon respiration and attention waves for the other two subjects. The breathing is quickened while the attention waves are slowed. This would not seem strange in the case of E., for, as we have seen, her attention rhythm is undoubtedly correlated with an entirely different physiological process from that effective for S. and B., but for B. we can only assume that a stimulus strong enough to shorten the breathing waves was not strong enough to more than slow the vaso-motor or attention waves. There is another series of complexities that arises when we consider attention efficiencies. These for S. and B. take exactly the same course as the length of the waves, but for E. we find that in one case the attention efficiency is increased while the breathing rate remains practically constant, and in another case it is decreased when the respiratory rhythm is lengthened, although in both cases the rate of the attention waves is slowed. This seems to indicate, if we use the effect upon respiration as a measure, that the first stimulus was only strong enough to facilitate the discharge of cortical cells, while in the other case it impeded the discharge of the cells or rendered them more liable to fatigue.

Taking all our results together and in connection with those

TABLE V.

Comparative Effect of Stimuli upon Attention and Respiration.

Subject S.

No.	Stimulation.	Visible Period.	Non Visible.	Total Respiration.	Attention Efficiency.
16	Normal	6.7	3.9	3.8	170
16	Induction	5.2	3.8	2.4	136
18	Normal	4.8	3.7	3.6	130
18	Induction	3.3	4.5	3.0	73
18	Smoking	6.1	5.0	6.5	123
19	Normal	6.3	6.4	5.2	98
19	Induction	3.8	4.8	3.9	81
20	Normal	6.7	6.7	6.9	100
20	Ether	5.0	5.4	3.8	92
20	Balsam	3.3	4.1	3.7	81

TABLE VI.

Effect of Stimulation upon Respiration and Attention Waves.

Subject E.

No.	Conditions of Experiment.	Visible Period.	Not Visible.	Total Respiration.	Attention Efficiency.
24	Normal	19.4	12.3	5.7	158
24	Induction	18.1	14.3	3.1	133
25	Normal	19.3	12.8	3.7	151
25	Induction	24.5	13.4	3.7	183

TABLE VII.

Respiration and Attention Waves.

Subject B.

No. of Tracing.	Conditions of Experiment.	Visible.	Not Visible.	Total Respiration.	Attention Efficiency.
21	Normal	4.9	2.1	3.2	236
21	Induction	5.2	2.0	2.8	262
22	Normal	6.0	2.8	3.5	214
22	Induction	6.8	2.7	3.1	253
23	Normal	6.0	2.8	4.3	222
23	Induction	7.9	2.8	2.7	284
23	After Stimulation Ceased.	5.4	2.8	2.9	196

obtained by Slaughter on the effect of voluntary exertion, it would seem that we may distinguish four different effects of stimulation upon attention waves. The stimulus at a certain intensity, or with some persons, shortens the length of the waves and lessens efficiency, other stimuli or the same stimuli with other subjects lengthen the waves and increase efficiency,

still other stimuli or the same stimuli on other individuals lengthen the wave and decrease the efficiency, while in still another case (voluntary effort) the waves are shortened and the attention efficiency increased. In the light of these contradictory results it would seem that we must distinguish carefully between the two different aspects of the attention and must decide that the two effects are not due to the same agencies. If we should consider a single stimulus in its varying intensities it would seem that the first influence at slight intensities is to quicken the respiration, to lengthen the vaso-motor waves and to render the attention more efficient. With a slight increase in the stimulus the vaso-motor waves are shortened, while the attention is rendered more efficient. With a yet greater increase in the intensity of the stimulus the vaso-motor waves are shortened and the attention efficiency decreased. The respiration rate is quickened by all the stimuli that we used. This series would account for all of the results except two tracings from E., and as we have noticed repeatedly these might be accounted for by the fact that her attention waves are of a different nature from those of the other subjects.

Physiologically it would be very easy to explain the different reactions of efficiency and length of wave if we think of the reinforcement from the medullary centers as merely marking off the rhythm of the fluctuations, while the variations in efficiency of the attention are explained as due to direct facilitation or inhibition of cortical activity. Then the rate would be influenced by all the factors that affect the vaso-motor rhythm just as the heart rate or respiration rate is affected, while the efficiency would need to be explained as due to a direct reinforcement or inhibition of the sensory cells as on the motor side the knee-jerk is affected by all sensory and motor impressions. It is easily conceivable that a stimulus strong enough to shorten the rhythm of the vaso-motor center would merely facilitate the action of the cortical cells, and that the relative susceptibility of these different cells would vary from time to time in the same individual and be different in different individuals.

We have not raised the question as to whether the intensity of the stimulus or its pleasantness or unpleasantness is responsible for the different changes that we notice, and our results are not sufficient to decide that question. We can at least assert that the feeling tone is only subsidiary, for we find that a decidedly unpleasant stimulus produces the same effect upon B. that a definitely pleasurable one has upon S. These and many other problems are suggested by our results, but we did not have time to go into them sufficiently to furnish a basis for discussion.

If we turn now to the direct bearing of our results upon the con-

troversy as to the nature and origin of the waves, the evidence is much clearer. The main thing in this connection is that the waves are influenced by external stimuli in very much the same way that the rhythms of heart and respiration are influenced. The direction of the influence and the nature of the stimulus are matters of very slight concern from this point of view. There is as much regularity in the effects as there is in the effect of similar stimuli upon either of the physiological rhythms or upon volume changes in the members.

But before we go on to our own explanation of the phenomena let us see if it is possible to explain the results in terms of either the Münsterberg[1] or the Leipzig theories. First as to the peripheral explanation. Is there any likelihood that a rhythm of fatigue and recovery in the muscles of accommodation in eye or ear could be influenced in one way by one kind of stimulus, in another way by another? There can of course be no direct effect upon the muscles in question, and even assuming that a muscle has a rhythm of fatigue and recovery that is of such short duration that it is very difficult to see how it could be affected by a central stimulus in the ways observed. Moreover, if there were direct stimulation we should expect it to show uniformity of results. As the action must be assumed to be of the same stimulus upon the same set of cells, the results from different individuals and at different times should be identical. Were the peripheral theory not already refuted by other facts it could offer no explanations for the phenomena that we have observed.

A very similar objection would hold against the purely central theory of Lange[2] that the fluctuations are due entirely to changes of the other ideas in consciousness at the time. This would go far towards an explanation of the oscillations in retinal rivalry, of the changing interpretation of figures in ambiguous perspective, and of the direction of the attention in general, but there is nothing at all in the ideas to account for a rhythm of any kind. If we lack a basis for an explanation of the fact of rhythm, we all the more lack any explanation of the changes in that rhythm under the influence of stimulation.

The simple Lehmann[3] theory would not be satisfactory because, in the first place, he did not hit upon the right circulatory rhythm and, in the second place, changes in blood pressure alone would not account for the variations in the efficiency, as all of the stimuli used would produce vaso-constriction while we see that they now reinforce, now weaken the attention.

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[1] Beiträge zur exper. Psychologie, II, pp. 69, ff.

[2] Phil. Stud., IV, pp. 390, ff. [3] Phil. Stud., IX, pp. 66, ff.

All of our results on the other hand become intelligible if we accept Slaughter's[1] conclusions that the rhythm of the attention depends upon the re-enforcement of the cortical centers by the intermittent discharges from the medullary centers and add to his explanation the statement that the general tone of central activity is raised or lowered,—that the discharge of cortical cells is re-enforced or inhibited by the action of external stimuli. We already have an indication of the effect of irrelevant processes to re-enforce the attentive processes in the work of Professor Münsterberg[2] and Miss Hamlin[3] on distraction.

One interesting subsidiary result of the work in correlating the respiration with the attention wave was a confirmation of Lehmann's result that the changes in the attention tended to come near the beginning of inspiration. Our results are not quite so clean cut as Lehmann's, but for both S. and B. the great majority of the changes come either during or just after inspiration. For S. 83% and for B. 74% came within less than one-half of the curve following the beginning of inspiration. For E. again the results are not clear, but, nevertheless, rather more than half of the changes in attention fall within this portion of the curve. There was also noticed a tendency for the attention waves to cover even numbers of respirations over considerable intervals of time. Most frequently for S. two respiratory periods corresponded to one period of visibility and one to a period of invisibility. This changed under stimulation to one respiratory period to each period of visibility and invisibility. That there should be some such more or less definite relation follows as a corollary from the fact that changes tended to occur at definite times in the respiratory rhythm. Both relations are easily understood in the light of Slaughter's conclusions that the attention waves are due to overflows from the medullary centers to the central nervous system in general. Although the respiratory wave is not strong enough in itself to overcome the Traube-Hering vaso-motor wave, it nevertheless asserts itself at the beginning and end of the other. If the most active part of respiratory activity comes just before the longer wave is becoming sufficiently strong to bring the gray ring to consciousness, it will assert itself and make the impression visible before it otherwise would appear, and in the same way if the vaso-motor impulse is waning during the period of inspiration the respiratory re-enforcement will keep the rings in consciousness until the end of its period of activity.

These facts have some bearing upon the physiological nature of the vaso-motor rhythm. For if it is affected in one way by

[1] *Amer. Jour. of Psy.*, as quoted.
[2] Psych. Review, I, pp. 39, ff.
[3] *Amer. Jour. of Psych.*, VIII, pp. 1, ff.

the stimuli while the respiration is affected in another way; it can hardly be regarded as originating in the respiratory center as Hering and Mayer have suggested.

SUMMARY.

1. The length of the attention waves is increased by stimuli of slight intensity, diminished by stimuli of greater intensity.
2. The efficiency of the attention, as shown by the ratio of the period of visibility of minimal stimuli to the period of invisibility, is increased by slight stimulation and decreased by more intense stimulation.
3. A large proportion of the changes in the attention take place during or just after inspiration.
4. The results of the experiments as a whole tend to confirm the theory that the attention waves are due to overflow effects from the vaso-motor and respiratory centers upon the cortical centers.

Our results suggest that the Traube-Hering and other circulatory rhythms can be more conveniently studied in man in their secondary form as attention waves than directly by the plethysmograph.